ITI8700: Knowledge Representation

Introduction to Semantic Parsing

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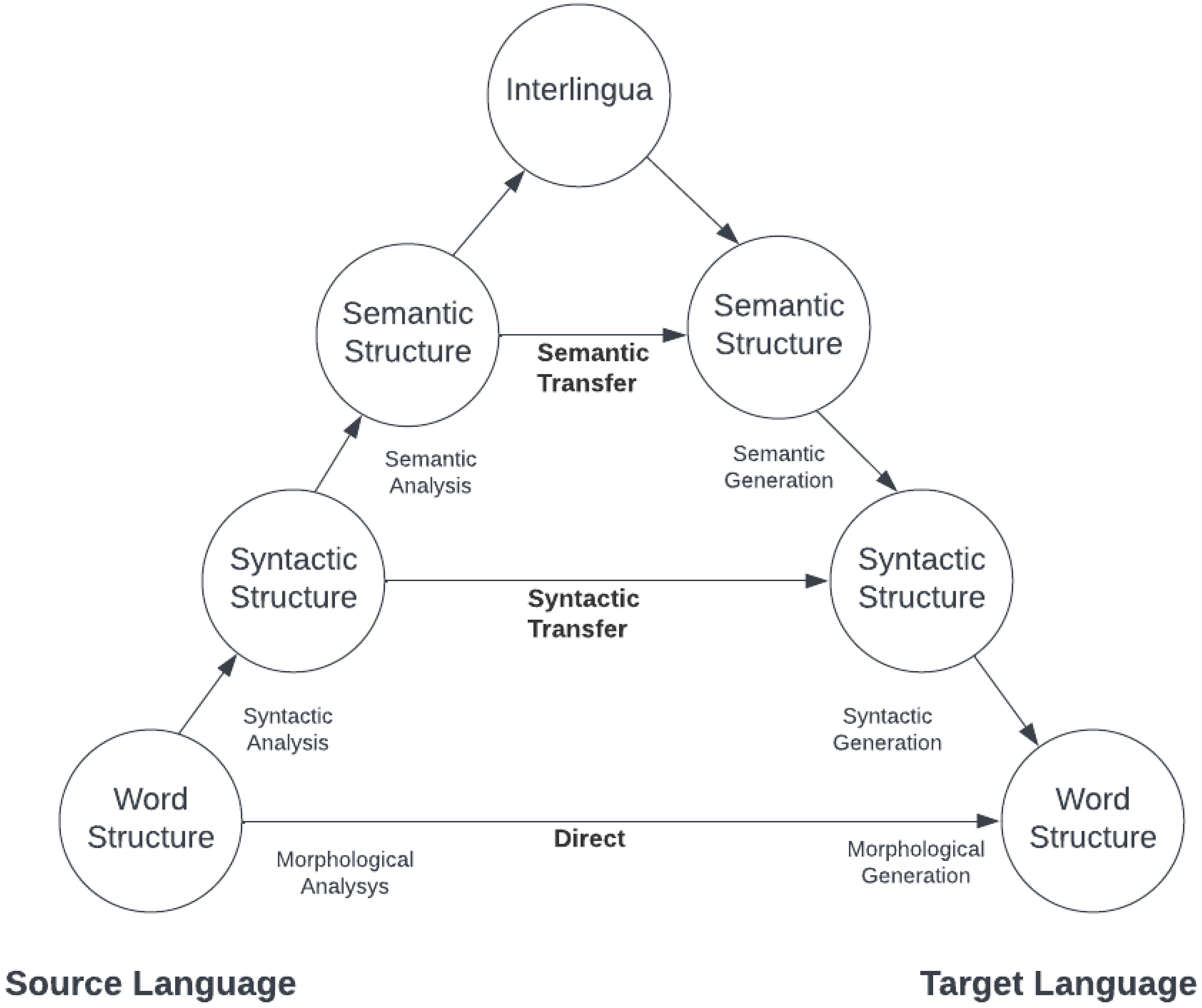
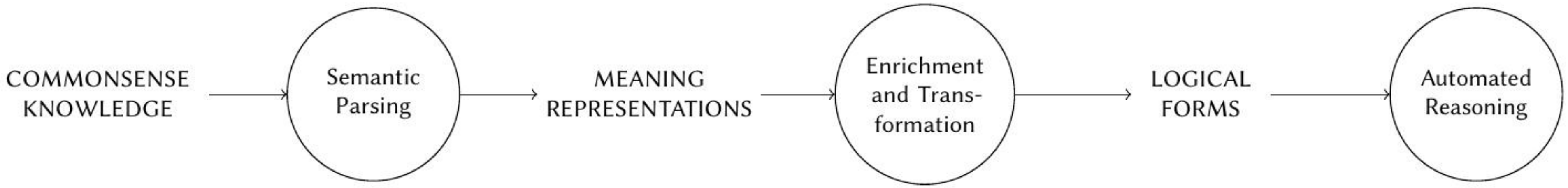
Commonsense Knowledge

Facts about the everyday world that a typical seven-year-old is expected to know including but not limited to space, time, objects, substances, environment, human psychology, societal norms, etc.


Interlingua
Semantic Structure
Semantic Structure
Semantic Transfer
Semantic Analysis
Semantic Generation
Syntactic Structure
Syntactic Structure
Syntactic Transfer
Syntactic Analysis
Syntactic Generation
Word Structure
Word Structure
Direct
Morphological Analysys
Morphological Generation
Source Language
Target Language

Semantic Parsing

The task of converting natural language utterances to formal, machine-understandable representations of their meaning.



A Semantic Parser for English

Why hard:

- Ambiguity: "I saw the man on the hill with the telescope"
- A large number of possible syntactic parse trees
- Roles of objects in the sentence hard to understand: subject, object, using, helper, place, time, …. (“A man opened the door” vs “A key opened the door”)
- Coreference resolution (“He saw it”)
- How to represent context/space/time etc?

Additional Challenges

- Fractured landscape
- No universal representation schemes
- No unified validation metrics - Maximum Common Edge Subgraph Isomorphism; Elementary Dependency Match; SMATCH; Precision, Recall, and F1 etc for different frameworks.
- Not enough annotated data

Semantic Parsing by Depth

- **Shallow** (Semantic Role Labelling) is concerned with identifying entities in an utterance and labelling them with the roles they play.
- **Deep** (Compositional Semantic Parsing) is concerned with producing precise meaning representations of utterances that can contain significant compositionality

Semantic Parsing by Anchoring Relation

- For **Bi-lexical** dependency graphs, the graph nodes correspond to surface lexical units.
- **Anchored** semantic graphs are characterized by relaxing the correspondence relations between nodes and tokens while still explicitly annotating the correspondence between nodes and parts of the sentence.
- For **unanchored** dependency graphs, the correspondence between the nodes and tokens is not explicitly annotated

Semantic Roles (Thematic Relations)

A semantic role is the underlying relationship that a participant has with the main verb in a clause.

Semantic Role	Definition
AGENT	The volitional causer of an event
EXPERIENCER	The experiencer of an event
FORCE	The non-volitional causer of the event
THEME	The participate most directly affected by an event
RESULT	The end product of an event
CONTENT	The proposition or content of a propositional evnet
INSTRUMENT	An instrument used in an event
SOURCE	The origin of the object of a transfer event
GOAL	The desination of an object of a transfer event
BENEFICIARY	The beneficiary of an event

Data Sources for Role Labels

Propbank (proposition bank) is a corpus that is annotated with verbal propositions and their arguments plus a lexicon defining those argument roles on a per-verb basis. https://propbank.github.io/

Unified Verb Index is a system which merges links and web pages from four different natural language processing projects: VerbNet, PropBank, FrameNet, Ontonotes (https://verbs.colorado.edu/verb-index/)

AMR Annotation Dictionary is a resource that describes AMR specific annotations, e.g. `regardless-91`: https://www.isi.edu/~ulf/amr/lib/amr-dict.html

Desired Attributes for Sematic Notation

1. **Verifiability.** System's ability to compare the state of affairs as described by a representation to the state of affairs as modeled in a knowledge base.
2. **Unambigious representation.** Words and sentences have different meaning representations in different contexts, but representations cannot be ambiguous.
3. **Canonical Form.** Distinct inputs meaning the same thing but having differents lexical utterances must have the same representation.
4. **Inference.** System must draw valid conclusions based on meaning of inputs and prior knowledge - propositions not explicitly stated but still logically derivable.
5. **Expressivness.** enough to handle a wide range of subject matter - ideally any sensible natural language utterance.

Many Different Annotations Schemes ..

- Abstract Meaning Representation (AMR)
- Universal Conceptual Cognitive Annotation (UCCA)
- Universal Dependencies (UD)
- Elementary Dependency Structures (EDS)
- Prague Tectogrammatical Graphs (PDT)
- Discourse Representation Structures (DRS)
- Universal Decompositional Semantics (UDS)

.. and many good parsers.

- But none that is ideally suited for our task.

Overview of Representation Schemes

Name	Unit of Annotation	Flavor	Format	Primary Languages
AMR	sentence	unanchored	Penman	English (+Chinese)
UCCA	sentence	anchored	XML	English (+4 others)
UD	sentence	bi-lexical	CoNLL-U	multilingual
EDS	sentence	anchored	DAG	English
PTG	sentence	anchored	DAG	English, Czech
DRS	passage	anchored	nested boxes	English
UDS	sentence	anchored	Predicates + UD (CoNLL-U)	English

Overview of Parsers

Notation	Parser	Platform	Stars	Forks	Commits	Last Commit
AMR	JAMR[6]	scala	192	50	825	March 2019
AMR	Transition AMR parser[7]	python	144	35	1838	November 2022
AMR	**amrlib**[8]	python	146	22	166	March 2022
UCCA	UCCA parser[9]	python	18	7	6	June 2019
UCCA	**TUPA**[10]	python	73	22	2135	December 2020
UD	UDepLambda[11]	java	85	22	225	July 2018
UD	uuparser[12]	python	77	26	125	October 2020
UD	stanza[13]	python	6400	830	3146	September 2022
EDS	Pydelphin[14]	python	68	24	1043	October 2022
EDS	HRG Parser[15]	python,java	9	0	4	October 2018
PTG	Perin[16]	python	41	5	36	Oct 04 2021
DRS	**TreeDRSparsing**[17]	python	5	2	59	March 2020
DRS	EncDecDRSParsing[18]	python	36	11	15	August 2019
UDS	**Predpatt**[19]	python	110	23	59	February 2021
UDS	MISO[20]	python	7	1	1019	September 2021

Our approach to semantic parsing: DIY

- We generate individual AMR parse trees from passage.
- We take the output of the Stanza Universal Dependencies Parser (Stanford)
- We apply UD parse as a constraint for AMR parse trees to:
    - classify the sentence
    - perform "sanity check" for AMR graph to identify and attempt to fix inconsistencies.
- We construct the sentence (and passage) level context objects.
- We apply sentence based semantic role mappings: ARG0 -> agent (from Propbank), mapping for custom AMR predicates: ‘have-org-role-91‘ -> ‘role‘
- And then convert the result to 1st-order logic.

Universal Dependencies

Cross-linguistically consistent treebank annotation for many languages, with the goal of facilitating multilingual parser development, cross-lingual learning, and parsing research from a language typology perspective.

The annotation scheme is based on an Stanford dependencies, Google universal POS tags and the Interset interlingua.

See also: https://universaldependencies.org

UD Example

Cats are animals.

```
root: animal [id:3 text:animals upos:NOUN xpos:NNS feats:Number=Plur]
  nsubj: cat [id:1 text:Cats upos:NOUN xpos:NNS feats:Number=Plur]
  cop: be [id:2 text:are upos:AUX xpos:VBP feats:Mood=Ind|Tense=Pres|VerbForm=Fin]
  punct: . [id:4 text:. upos:PUNCT xpos:.]
```

Universal Conceptual Cognitive Annotation (UCCA)

The central idea of the project is to analyze and annotate natural languages using purely semantic categories and structure (a graph). Syntactic categories and structure are not part of the manual annotation, and are ideally learned implicitly by the parsers.

Base element of the foundational layer is a *scene* - describing movement, action or event with optional spatial and temporal relations.

https://universalconceptualcognitiveannotation.github.io/

Demo (currently offline): http://ucca-demo.cs.huji.ac.il/

UCCA Example

Cats are animals.

```
corpus-min_0000:
  Light verbs:
    1.22->1.24 [F are]
  Predicate nouns:
    1.21->1.22 [P [C Cats] [F are] ]
  Center:
    1.1->1.2 [C animals]
    1.22->1.23 [C Cats]
  Punctuation:
    1.1->1.3 [U .]
  Participant:
    1.1->1.22 [A [C Cats] [F are] ]
    1.1->1.23 [A Cats]
  Function:
    1.22->1.24 [F are]
```

Discourse Representation Structures (DRS)

DRS is a representation scheme based on Discourse Representation Theory. In contrast to ordinary treebanks, the units of annotation in the corpus are texts rather than isolated sentences. Basic DRSs consist of discourse referents like x representing entities and discourse conditions like $man(x)$ representing information about discourse referents. The corpus is based on Groningen Meaning Bank that annotates English texts with formal meaning representations rooted in Combinatory Categorial Grammar.

See also: LangPro. https://naturallogic.pro/LangPro/

DRS Example

Cats are animals.

```
DRS-0(
    cat( X1 )
    animal( X1 )
    be( E1 )
    Agent( E1 X2 )
    Patient( E1 X3 )
    now( T1 )
    Temp_included( E1 T2 )
    Equ( T2 T2 )
)
```

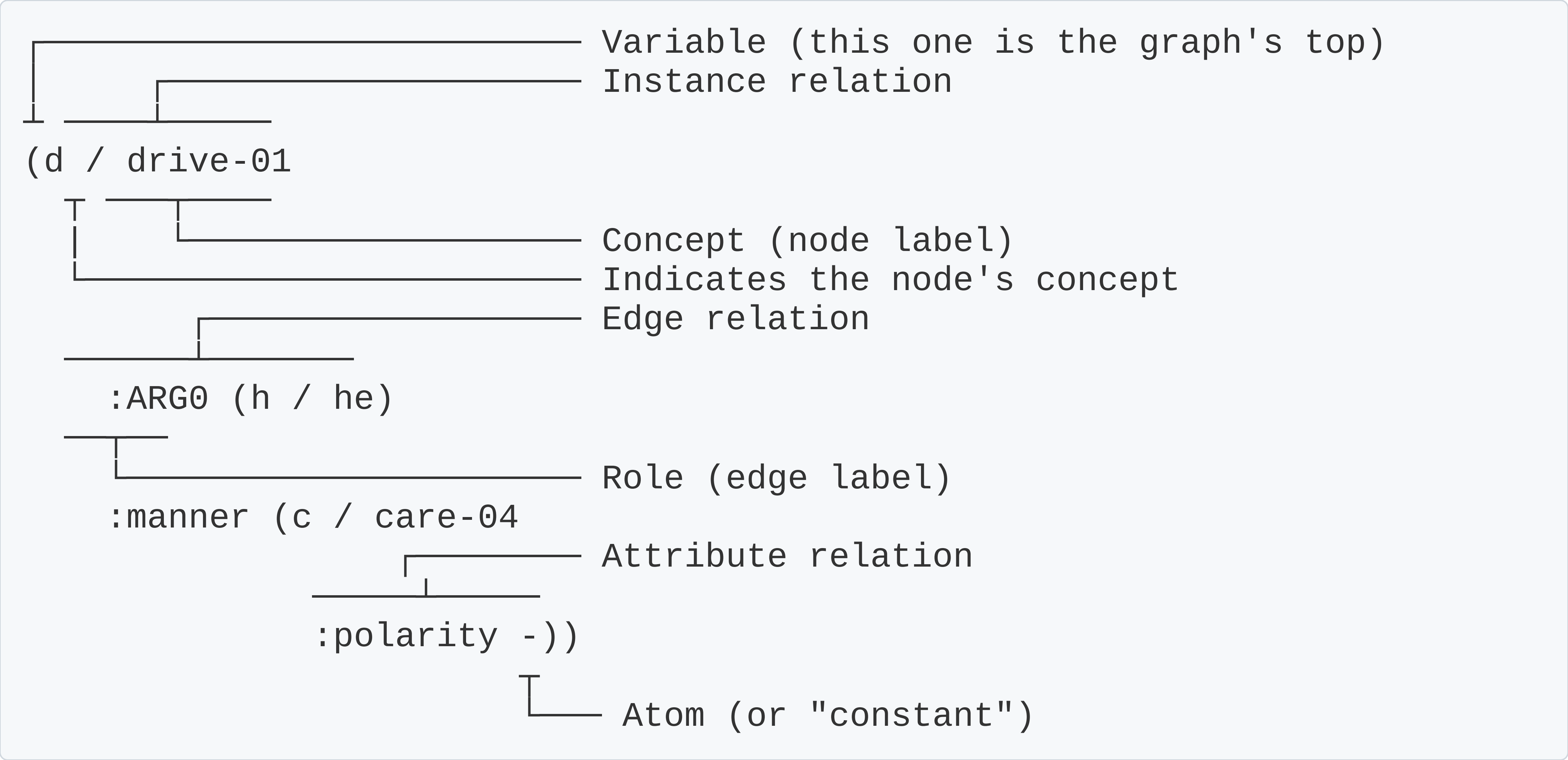
AMR

Abstract Meaning Representation is a semantic formalism based on propositional logic and the neo-Davidsonian event representations where each representation is a single-rooted, directed graph. AMR is strongly biased towards English though it does support multilingual meanings. Its concepts are either English verbs, PropBank framesets, or specific keywords. AMR also supports NER, question detection, within-sentence co-reference, modality and question identification.

Benefits of AMR

- Tools for processing: https://penman.readthedocs.io/en/latest/api/penman.html
- Can be represented as triples: manageable post-processing
- Penman notation both human and machine-readable.
- Question detection with `amr-unknown` keyword.

Penman notation



Example

Brutus stabs Caesar with a knife.

AMR parse graph

```
(s / stab-01
      :ARG0 (p / person
            :name (n / name
                  :op1 "Brutus"))
      :ARG1 (p2 / person
            :name (n2 / name
                  :op1 "Caesar"))
      :instrument (k / knife))
```

Example

Brutus stabs Caesar with a knife.

UD parse

```
root: stab (stabs) upos:VERB xpos:VBZ lemma:stab ↵
        feats:Mood=Ind|Number=Sing|Person=3|Tense=Pres|VerbForm=Fin]
  nsubj: Brutus upos:PROPN xpos:NNP lemma:Brutus ner:S-PERSON]
  obj: Caesar upos:PROPN xpos:NNP lemma:Caesar ner:S-PERSON]
  obl: knife upos:NOUN xpos:NN lemma:knife]
    case: with upos:ADP xpos:IN lemma:with]
    det: a upos:DET xpos:DT lemma:a]
```

Constructing a logical Form

From Jurafsky: 15.4 "Event and State Representation"

1. Events are captured with predicates that take single event variable as an argument. Events are denoted by verbs.
2. There is no need to specifiy a fixed number of arguments for a given FOL predicate: as many roles and fillers can be glued on, e.g. `stabs(Brutus, Caesar) & with(knife) & in(agora)`
3. No more roles are postulated than are mentioned in input.
4. The logical connections between closely related inputs that share same predicate are satisfied without the need for additional inference.
5. Syntactic arguments form the arguments of semantic predicates.

Constructing a logical form

Construction of logical form consists of the following steps:

1. Find predicates, specify their arguments (number, type)
   1.1 Concepts and events - `predicate/1`
   1.2 Roles - `predicate/2`
2. Construct corresponding atoms
3. Divide atoms on same level into groups
4. Specify connectives between atoms of each group and construct corresponding formulas.

Constructing a logical form

5. Divide formulas and/or any of the remaining atoms of the same level into groups. If there are no groups go to step 7
6. Specify connectives between elements of each group
7. Specify quantifers for the variables.
8. Construct final FOL formula.

Example

Brutus stabs Caesar with a knife.

Generated Context


```
{ 'amr_root': {'lemma': 'stab', 'upos': 'VERB'},
  'entities': [ {'text': 'Brutus', 'type': 'PERSON'},
                {'text': 'Caesar', 'type': 'PERSON'}],
  'idx': 0,
  'question': False,
  'type': 'sit',
  'ud_root': {'lemma': 'stab', 'upos': 'VERB'}}
```

Example

Brutus stabs Caesar with a knife.

Clausified Form

```
[
  ['Agent', 'stab-01', 'person'],
  ['Patient', 'stab-01', 'person0'],
  ['instrument', 'stab-01', 'knife'],
  ['hasName', 'person', 'Brutus'],
  ['hasName', 'person0', 'Caesar']
]
```

Still Problems with Ambiguity

"The sailor killed the pirate with a sword."

We cannot infer whole meaning without knowing the context.

Constructing the Context

1. Keeping track of sentence order.
2. Keeping track of named entities.
3. Classifying the sentence type:
    - *Conceptual*: Typically, they describe concepts or relations between them. Example: Elephant is a big animal.
    - *Facts*: Named entities not dependent on uncommon circum-stances. Example: Rome is the capital of Italy.
    - *Situational*: A concrete situation and events happening within this situa tion. Example: Brutus stabbed Caesar with a knife.

Work To Do

- **Compound sentence segmentation**. Given compound sentences they are not split before parsing, resulting in increased complexity of generated logical forms (due to connectives).
- __Context order and merging
- **Question detection and scope.** Question parsing is not implemented in the current version of the system.
- **.. and many more**

Thank you.